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Laboratory Method of Testing Energy Performance of Fan-Filter Units

Version 1.3 (2005)

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Foreword

This standard test method is developed by the Lawrence Berkeley National Laboratory (LBNL), in collaboration with the Industrial Technology Research Institute (ITRI) of Taiwan and members of the Project Advisory Committee (PAC) for the high-performance building project supported by the California Energy Commission. The standard method intends to provide a laboratory method for testing fan-filter units. This document focuses on their energy and aerodynamic performance. The use of this method can provide comparable information on energy performance of fan-filter units (FFUs).

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1. Purpose

The purpose of this document is to provide a standard test procedure for laboratory characterization of fan-filter units by determining energy performance in terms of unit airflow rate, static pressure, electric power demand, and total pressure efficiency. The objective is to provide a method for performance testing and reporting based upon consistent procedures. This can then be referenced by and integrated into a relevant industry recommended practice or standard.

1.1 Intent

This document is intended for industry use, including fan-filter-unit (FFU) manufacturers, end users, utility companies, and designers. It provides a means of obtaining energy performance of an FFU at selected conditions. It is not the purpose of this document to guide field-testing, although some of the techniques can be applied to field-testing.

1.2 Review and Amendment

This document is subject to review and amendment as experience in its use and technologies advance.

2. Scope

This document includes terminology used in the filter and cleanroom industry. This document is intended to apply specifically to energy and air movement performance of fan-filter units. It may be used as the basis for gathering baseline information and for comparison of fan-filter units' energy performance equipped with typical filters (e.g., ULPA or HEPA). This procedure may be used in development of a more comprehensive procedure such as the Recommended Practice to be developed by the Institute of Environmental Sciences and Technology (IEST).

The standard test procedure is limited to test FFUs with filter media for removing particulates under normal cleanroom environmental conditions. This document is not intended to cover filters used for controlling airborne molecular contamination (AMC). Users of FFUs dealing with AMC should refer to relevant publications for more information, such as IEST RP CC 035 "Design Considerations for Airborne Molecular Contamination Filtration Systems in Cleanrooms."

Relevant codes may be applicable to the construction and performance of fan filter units. These codes should be made part of the agreement between the customer and supplier. In addition, this document does not cover testing procedures for

- Acoustic performance
- Vibration performance
- Particulate filtration efficiency
- Airborne molecular contamination filter media
- Outlet airflow uniformity

3. Nomenclature and Terms

- **Q (Unit Airflow Rate):** Actual airflow rate through the FFU tested under a specific static pressure across the unit, in m^3s^{-1} or cubic foot per minute (cfm).

- **V (Airflow Speed):** Unit airflow rate divided by the net FFU face area under a specific static pressure across the unit, in m/s or foot per minute (fpm).

- **V_n (Nominal Airflow Speed):** Unit airflow rate divided by the gross FFU face area under a specific static pressure across the unit, in m/s or fpm.

- **p_{stat} (Static Pressure),** in Pa or inch water.

- **p_{total} (Total Pressure):** Sum of the static pressure and the velocity pressure, in Pa or inch water.

- **Fan Wheel Rotational Speed**: Number of rotation per minute (RPM).

- **P_t (Total Electric Power Demand):** Total electric power input to operate the FFU at certain airflow conditions, including fan motor, controller, etc., in kW or HP. In the cases that lighting is incorporated into an FFU, the gross total electric power demand should include lighting.

- **P_v (Airflow Dynamic Power):** The dynamic power of the airflow through an FFU, in kW or HP.

- **EPI (Energy Performance Index):** Unit's total electric power demand normalized by the airflow rate of an FFU, in W/(m^3h^{-1}) or W/cfm.

- **E_t (Total Pressure Efficiency):** Ratio of airflow dynamic power to the total power input to an FFU, in % (dimensionless).

4. Instrumentation, Testing Setup, Control and Methods

4.1 Key testing parameters

The purpose of conducting laboratory testing is to obtain characterization data of energy performance for FFUs under various operating conditions, and to provide performance reporting for specific FFUs with HEPA/ULPA filters. In addition to reporting relevant characteristics of an FFU, such as filtration efficiency and filter size, this document specifies the required tests applicable to this standard and suggests additional (or optional) tests relevant to the energy performance.

The required tests include the unit airflow rates (or actual airflow speeds), total electric power demand, and the static (and total) pressures across the FFU. The total electric power demand shall be measured at a range of airflow rates with the actual static (total) pressure gain, and should include the power consumption of other components associated with the FFU, such as embedded lighting and motor controller.

The additional (optional) tests may include airflow uniformity.

4.2 Key instrumentation and accuracy

4.2.1 Key instrumentation

4.2.1.1 Unit airflow rate

The amount of airflows through the FFU being tested shall be controllable within an operable range for the FFU. The test setup should be consistent with other standard test methods developed by ASHRAE/AMCA. The measurements and evaluation of FFU performance shall include various operation conditions in order to generate performance curves (e.g., similar to fan's aerodynamic performance). The setup shall ensure no air leaks between the enclosed testing system and its ambient space. The measurement of airflows through the FFU can be conducted upstream or downstream of the FFU, with an uncertainty to be within ±5%.

4.2.1.2 Static and total pressure

Record the static and total pressure across the unit.

4.2.1.3 Total electric power demand

The total electric power demand shall be measured at a range of airflow rates with the actual static (total) pressure gain, and should include the power consumption of other components associated with the FFU, such as embedded lighting and motor controller. The electric power measurement shall include electric current, voltage, true mean power, and frequency.

4.2.1.4 RPM meter

Record the RPM for each test conditions.

4.2.2 Accuracy

It's required to obtain accurate measurements of unit airflow rates at various operating conditions. The unit airflow rate, airflow speed, total electric power demand shall be recorded at a range of operating points adjusted by varying the static pressures across the FFU.

Airflow measurement setup contains a multiple-nozzle bank for recording airflow rates through the tested unit. The air from the immediate downstream of the FFUs can be discharged to the atmosphere or a space with a specific static pressure. The following diagram conceptually illustrates the experimental setup for measuring airflows, static (and total) pressure, and total electric power demand. Measuring the airflow using this setup, which is consistent with ASHRAE/AMCA standard, can provide most accurate airflow measurement (e.g., 1%).

4.3 Testing setup

4.3.1 Principles

The amount of airflows through the FFU being tested shall be controllable within a reasonable range for the FFU. The measurements and evaluation of FFU performance shall include multi-points for various operation conditions in order to generate performance curves (e.g., similar to fan's aerodynamic performance). The setup or configuration shall ensure no air leaks between the enclosed testing system and the ambient environment. The measurement of airflow through the FFU can be conducted upstream or downstream of the FFU, with an error within ±3% or 5 cfm.

4.3.2 Testing device layout

For laboratory testing, ideally the FFU tested can be mounted horizontally or vertically on the exit of the air chamber, or in the inlet of a sealed duct leading to an air chamber.

4.4 Control and Methods

To control the airflow rate across the FFU tested, an ancillary fan and a damper may be needed to modulate static (and total) pressures and airflows across the FFU.

4.4.1 FFU with a single-speed-drive motor

The FFU shall be tested at the fixed fan-wheel rotational speed, while adjusting damper positions modulates static pressures and airflows across the FFU. The corresponding static pressure, unit airflow rate (and airflow speed), and total electric power demand shall be recorded.

4.4.2 FFU with a multi-speed-drive motor

The FFU shall be tested for each fixed level of fan-wheel speeds offered by the motor. Adjusting damper positions modulates the static pressure across the FFU. The corresponding static pressure, unit airflow rate (and airflow speed), and total electric power demand shall be recorded for each level of rotational speed.

4.4.3 FFU with a variable-speed-drive (VSD) motor

For an FFU equipped with speed modulation device using a VSD motor, the fan motor in FFU shall be set at various speeds for testing. Similar to the FFU with multi-speed-drive motor, the corresponding static pressure, unit airflow rate (and airflow speed), and total electric power demand shall be recorded for each level of the fan-wheel's rotational speeds, e.g., 20%, 40%, 60%, 80%, and 100% of the maximal speed.

4.5 Measurements

4.5.1 Unit airflow rate measurement

This procedure provide two options to obtain unit airflow rates. The unit airflow rate, airflow speed, total electric power demand shall be recorded at a range of operating points adjusted by varying the static pressures across the FFU.

The setup contains a multiple-nozzle bank for recording airflow rates through the tested unit. The air from the immediate downstream of the FFUs can be discharged to the atmosphere or a space with a specific static pressure. The following diagram illustrates the experimental setup for measuring airflows, static (and total) pressure, and total electric power demand. Measuring the airflow using this setup, which is consistent with ASHRAE/AMCA standard, can provide most accurate airflow measurement (e.g., 1% uncertainty) and may best emulate common setting in real cleanrooms.

Figure 1 illustrates a conceptual setup using nozzles to measure airflow upstream of airflow path directed through an FFU. For simplicity, the FFU is shown to be vertical, although a horizontal FFU is desired to best emulate common FFU applications in cleanrooms.

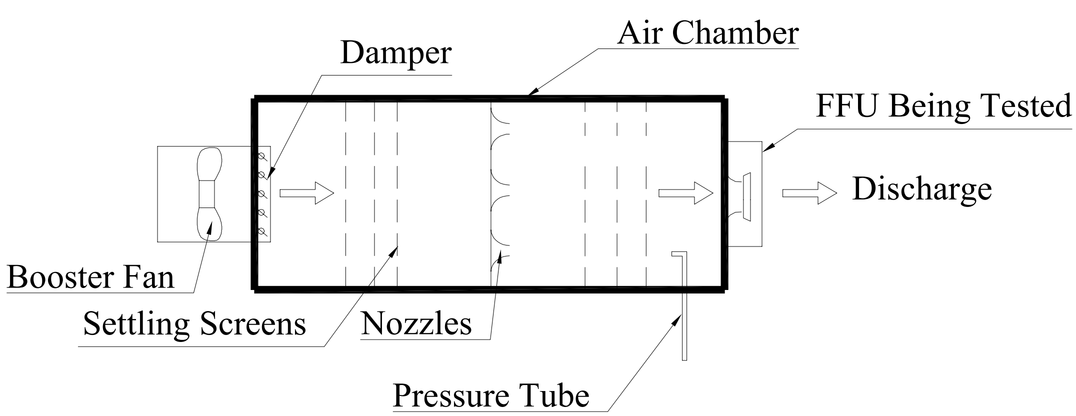

Figure 1 Conceptual test setup

4.5.2 Static (total) pressure across the FFU

Concurrent measurements of the static (total) pressure across the FFU shall be recorded. In addition, concurrent pressure difference across the HEPA or ULPA filter should be measured.

4.5.3 Power supply and total electric power demand

Power supply to the FFU shall be in compliance with the product specifications. Deviation of power supply from the supplier-specified requirements may produce different FFU performance. Appropriate power meters shall be used to measure true power demand of the unit.

Concurrent measurements of total electric power demand supplied to the FFU shall be recorded. The recorded parameters may include true electric power demand, frequency, electric current and voltage, and power factor. In the case that lighting device is integral to the FFU, the total electric power demand shall include its power demand.

4.5.4 Ambient conditions

The test can be conducted at various ambient conditions. Cautions must be taken to ensure that the airflow through the testing device is isothermal; otherwise, necessary corrections shall be undertaken to account for the impact on the measured data. The ambient conditions (elevation, temperature, and humidity) and the airflow conditions shall be recorded.

5. Reporting Test Results

5.1 Descriptive Parameters

5.1.1 Physical size

The physical size, weight, noise, vibration, efficiencies, maintenance, capacity, and reliability of an FFU are among the major considerations of product design and selection. Physical dimensions (height, length, and width) of the fan filter unit and weight shall be reported.

5.1.2 Filter characteristics

5.1.2.1 Filter type, material, and dimensions shall be reported. The net face area of the FFU shall be reported.

5.1.2.2 Particulate filtration efficiency shall be specified. This will be based upon the data information from filter supplier, e.g., 99.99% for 0.3 micron-meter particles. Details of specifying acceptable filter testing standards can be found in relevant literatures, such as IEST RP-CC-006 or ISO 14644-3.

5.1.2.3 Pressure resistance across the HEPA or ULPA filter may be reported to provide its performance with the change of airflow rates.

5.1.3 Fan and motor

It is common that an FFU is equipped with backward inclined centrifugal impellers. The report shall, nonetheless, include the type and size of the fan wheel and motor used in the FFU. For example, the parameters should include the following: impeller diameter, number of blades, and blade pitch.

An FFU can be equipped with an AC external rotor motor (single-phase or three-phase) or a DC external rotor motor. Constant-speed-drive motors are commonly employed; however, some motors are equipped with variable-speed-drive (VSD) to allow on-field adjustment of fan wheel speeds. The option of adding a VSD is to provide an easy means to adjust airflow in the field if values are above or below prescribed criteria for some applications.

5.2 Test Conditions

5.2.1 Unit airflow rate and fan-wheel rotational speed

Actual unit airflow rates (and/or airflow speeds) shall be recorded corresponding to various static pressures.

The fan wheel rotational speeds (RPM) should be recorded and reported.

5.2.2 Static pressure across the FFU

To generate various testing points, the static pressure shall be controlled at various levels (e.g., from zero to 0.2-inch water through 1.5-inch water). The performance metrics can then be obtained for a specific static pressure (e.g., 0.5-inch water) or a specific actual unit airflow rate (e.g., 70 fpm, or 550 cfm for a 2-by-4-ft FFU).

5.2.3 Total electric power demand

Total electric power demand shall include the fan, frequency drive motor, speed control device, etc. In the cases that lighting is incorporated into an FFU, the gross total electric power demand should include lighting. Power factors shall be reported.

5.2.4 Ambient air condition

Recorded air conditions shall be converted to standard air condition for calculating air density. The recorded data (elevation, temperature, and humidity) shall be used for the air density conversion to the equivalent standard condition (i.e., 1 atm, 20°C).

5.3 Key Performance Metrics

5.3.1 Unit airflow rates (or actual airflow speeds) corresponding to various static pressures Maximum unit air flowrate shall be reported.

5.3.2 Total pressure efficiency at various static pressures or unit airflow rates. The total pressure efficiency changes with operating pressures and airflow rates

5.3.3 Total electric power demand corresponding to various static pressures across the FFU. The total electric power demand should also be reported for a certain unit airflow rate (or actual airflow speed) with the actual static pressure gain.

5.3.4 Energy performance index (EPI) corresponding to various static pressures or airflow rates. EPI can be reported directly based upon a selective static pressure of concerns, e.g., 125 Pa (or 0.5-inch water). As an alternative, EPI can be reported for a specific unit airflow speed (e.g., 70 fpm) along with the actual static pressure gain.

5.4 Reporting Requirements and Format

5.4.1 Descriptive parameters specified in Section 6.1 shall be reported.

5.4.2 Experimental data obtained through the testing shall be reported to provide performance curves with a range of operating conditions tested.

5.4.2.1 The report shall contain performance data of the static (and total) pressure gains, total electric power demand, total pressure efficiency, and EPI as a function of unit airflow rate under a range of fan-wheel rotational speeds as applicable.

5.4.2.2 In addition to reporting data, the performance curves should be presented as a function of actual airflow speeds. The report shall include specification of sizes of the fan and fan-filter unit, and the motor speed control for the performance curves produced.

5.4.3 All experimental data curves reported shall be converted to the standard atmospheric condition.

6. References and Resources

1) ISO. 2002. ISO 14644-3 Cleanrooms and associated controlled environments — Part 3: Metrology and test methods. The Institute of Environmental Sciences and Technology (IEST). Rolling Meadows, IL.

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12) ANSI/ASHRAE Standard 51-1999. Also AMCA 210-99. Laboratory Methods of Testing Fans for Rating.

13) ASHRAE. 1987. ASHREA Standard 41.2 (RA 92) - Standard Methods for Laboratory Airflow Measurements.

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16) Xu, T. and M. Jeng. 2004. "Laboratory Evaluation of Fan-filter Units' Aerodynamic and Energy Performance," *Journal of the IEST*, Volume 47: 116-120, Institute of Environmental Sciences and Technology (IEST), Illinois. Lawrence Berkeley National Laboratory Report LBNL-54250.

7. Addendum

Informative (not part of this standard test method)

7.1 Non-energy performance

Methods of testing acoustics, particulate filtration efficiency, and filter leak have been addressed in specific industry standards or recommended practices. Although the measurements of these parameters are not covered in this procedure, FFU manufacturers should make this information available as part of the product specifications. Vibration issue is important and needs further development outside the scope of this document.

7.2 Flow uniformity - optional

In addition to filtration performance, FFU's airflow uniformity is an important element to characterize the overall performance of the FFU with HEPA or ULPA filters; therefore, airflow uniformity is an important element required for cleanroom certification, and should be part of the product specification. Because cleanroom certification would involve operational testing in facilities, relevant industry standards or guidelines for recommended practices address certain aspects of uniformity testing. For example, users can refer to IEST RP-CC-002.2 "Unidirectional Flow Clean Air Devices" and IEST RP-CC-006.2 "Testing Cleanrooms" for relevant information.

7.3 Interpretation of results

Results from using this standard test method should not automatically be considered as being "certified." Although an AMCA certified facility is not necessarily required for performance testing using this procedure, results from using this procedure in a certified facility can be certifiable by a recognized entity such as AMCA.